

DISTRIBUTION OF HANGING GARDEN VEGETATION ASSOCIATIONS ON THE COLORADO PLATEAU, USA

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ABSTRACT

Hanging gardens are island-like habitats dominated by mesophytic-hydrophytic plant communities, growing on seeps on the xeric canyon walls of the Colorado Plateau in the American West. We measured the abundance of species and physical microhabitat characteristics of 73 individual hanging gardens during the growing seasons of 1991–1993. Cluster analysis of a simplified Morisita community similarity index matrix produced four distinct clusters of herbaceous vegetation: *Adiantum capillus-veneris*, *Aquilegia micrantha*, *Calamagrostis scopulorum*, and *Cirsium rydbergii* Herbaceous Associations. These associations are based on species abundance and are floristically described via summary tables showing dominance, constancy, and presence of hanging-garden endemic species. Univariate comparisons of species richness, hanging garden size, and dominance show that the *A. capillus-veneris* and *A. micrantha* associations tend to be smaller, less species rich, and have higher dominance values than the *C. scopulorum* and *C. rydbergii* associations. Two associations were dominated by species endemic to hanging gardens: *Aquilegia micrantha* and *Cirsium rydbergii*. These four hanging garden associations contrast with previous local vegetation surveys which place all hanging garden communities into one vegetation type despite the lack of a common dominant or constant species.

RESUMEN

Los jardines colgantes son hábitats como islas dominados por comunidades de plantas mesófitas-hidrófitas, que crecen en las filtraciones de las paredes secas de los cañones de la Meseta de Colorado en el oeste de los Estados Unidos. Medimos la abundancia de especies y características físicas del micro hábitat de 73 jardines colgantes individuales durante las épocas de crecimiento de 1991–1993. El análisis de cluster de una matriz simplificada del índice de similitud de la comunidad de Morisita produjo cuatro grupos distintos de vegetación herbácea asociada: *Adiantum Capillus-veneris*, *Aquilegia micrantha*, *Calamagrostis scopulorum*, y *Cirsium rydbergii*. Estas asociaciones se basan en la abundancia de las especies y son descritas florísticamente en una tabla que muestra la dominancia, la constancia, y la presencia de las especies endémicas en los jardines colgantes. Las comparaciones univariantes de la riqueza de especies, el tamaño del jardín colgante y su dominancia muestran que las asociaciones de *A. capillus-veneris* y de *A. micrantha* tienden ser más pequeñas, menos ricas en especies, y tienen valores más altos en la dominancia que las asociaciones de *Calamagrostis scopulorum* y de *Cirsium rydbergii*. Dos asociaciones están dominadas por especies endémicas de los jardines colgantes: *Aquilegia micrantha* y *Cirsium rydbergii*. Estas cuatro asociaciones de jardines colgantes contrastan con los estudios locales previos de vegetación que colocan todas comunidades del jardines colgantes en un solo tipo de vegetación a pesar de la falta de una especie común, dominante o constante.

The lush plant growth of hanging gardens on canyon walls in the entrenched drainage system of the Colorado Plateau attracted the attention of early botanists and pioneers (Welsh & Toft 1981). Powell (1895), the first scientific explorer of the Colorado River canyon, noted the “oak glens,” ferns and mosses on moistened sandstone, and rich vegetation associated with seeps “in marked contrast to the general appearance of naked rock” within what is now Glen Canyon NRA (Fig. 1). Many subsequent visitors have noted the island-like boundary between hanging gardens and their xeric canyon-wall surroundings (Woodbury 1933; Malanson & Kay 1980; Welsh 1989). The microclimate of the larger hanging gardens often contrasts sharply with the surrounding high desert: water is abundant, soils are moist, and canyon walls offer periodic shade (Malanson 1980; Welsh & Toft 1981). Hanging gardens are also relatively small, mostly less than one hectare, further contributing to the island-like effect, visually similar to the inselberg (granitic and gneissic rock outcrop) communities found in North and South America, Africa, and Australia (Barthlott & Porembski 2000). However, in contrast to the much better studied inselberg systems (Groger & Barthlett 1996; Porembski et

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


FIG. 1. Study areas and locations of hanging garden plant communities sampled on the Colorado Plateau during the summers of 1991–1993.

al. 1996; Sarthou & Villers 1998), hanging gardens are moist vegetation islands rather than xeric vegetation islands (Szarzynski 2000) embedded within bedrock expanses.

Hanging gardens are dominated by mesophytic and hydrophytic herbaceous vegetation (Malanson 1980; Welsh & Toft 1981; Welsh 1989) which develops at and downslope from ground-water seepage zones within the exposed aquifer along crossbedded sandstone canyon walls. Ground-water “sapping” erosion processes (Higgins 1984; Laity & Malin 1985; Baker 1990; Dunne 1990; May et al. 1995) produce the physical hanging garden habitat: perennially wet rock walls and/or wet, subirrigated colluvial soils (May et al. 1995). They are often located in wet theater-headed valleys formed “by weakening or removal of basal support as a result of enhanced weathering and erosion” by water seepage (Laity & Malin 1985, p. 203). These diffuse-discharge,

seepage erosion areas are the result of ground water moving through highly transmissive aquifers, down the dip planes to where impermeable layers within or below an aquifer intersect a canyon wall, as well as along deep fractures within the aquifer (Laity & Malin 1985; Dunne 1990; May et al. 1995), and are distinctly different from point-source erosion processes caused by discharge at springs (Higgins 1984). Ground-water sapping processes provide both the raw material for colluvial soil development and water for subirrigation of vegetation growing on that habitat.

Floristic work has elucidated the flora associated with hanging garden habitats (Eastwood, 1896; Clover & Jotter 1944; Harrison et al. 1964; Welsh & Moore 1968; Welsh 1986a, b; Shultz et al. 1987; Welsh 1989), including several species endemic to hanging gardens (Harrison et al. 1964; Welsh 1989; Fowler et al. 1995; Welsh et al. 2003). Microhabitat affinities for several hanging garden plant species have also been described (Welsh & Toft 1981; Welsh 1989).

Woodbury (1933), Welsh and Toft (1981), and May et al. (1995) have proposed hanging garden classification systems based on microhabitats and geomorphology. Woodbury (1933) briefly described hanging garden seral associates in Zion NP as part of a park-wide vegetation classification monograph. Malanson (1980, 1982) and Malanson and Kay (1980) measured frequency of species occurrence, species richness, and calculated similarity indices to investigate the effects of flooding frequency, dispersal distance, plant dispersal types, and physical habitat characteristics on species assemblages in 29 small hanging gardens in Zion NP. These studies did not measure species abundance or take a phytosociological approach. In this study, we measured canopy coverage for each vascular plant species on 73 hanging gardens in a regional study, classified them into herbaceous associations, and examined the regional distribution of those associations.

STUDY AREA

The study area was located on the Colorado Plateau in Utah and Colorado (Fig. 1), a major portion of the known geographic range of hanging gardens. Field work was conducted on hanging gardens at seven National Park Service units during the summers of 1991–1993: Arches NP, Canyonlands NP, Capitol Reef NP, Dinosaur NP, Glen Canyon NRA, Natural Bridges NM, and Zion NP (Fig. 1). We selected most of the larger, known hanging gardens in each park unit and many smaller ones that we were able to locate. Hanging gardens that were too small to use the vegetation sampling methods described below were excluded from this study.

METHODS

We defined hanging garden habitats as predominately herbaceous vegetation growing on permanently wet soil and wet rock surfaces, originating from seeps on canyon walls in sandstone aquifers (Malanson & Kay 1980). Hanging gardens were delineated from the surrounding bedrock and xeric soils by the presence of wet rock surfaces and/or wet soils (May et al. 1995). The hanging garden boundary with a riparian community, when present, was defined by where colluvial soils stop and alluvial soils begin (May et al. 1995).

Each hanging garden was visually separated into the following microhabitats: seepline, wet wall, ledge, and wet colluvial soil to stratify vegetation sampling. Seeplines are drier, linear microhabitats that develop at fractures in the sandstone or, more often, at horizontal impervious bedding planes on canyon walls and at the back of small alcoves. Wet walls included inverted, vertical, or sloping rock surfaces below seeps that moisten the sandstone surface or have sufficient discharge to produce thin sheet flows of water with occasional drip points. Ledge microhabitats are of sufficient horizontal width to support strips of hydrophytic vegetation in depressions with wet, saturated soil. Wet colluvial soil microhabitats are complex in shape and composed of wet, subirrigated colluvial soils located downslope of seepage zones, sometimes within and/or below a larger alcove created by groundwater sapping. Since these soils develop directly from the weathering of sandstone, they are obviously very sandy and may be virtually saturated near seeps.

We collected data on the following physical parameters: length of major axis, aspect, elevation, map location, and geologic formation. Hanging garden size was calculated from major axis length and the mean of ten equally spaced widths taken during vegetation sampling.

Vegetation

On each hanging garden, the herbaceous, vascular plant vegetation stratum was systematically sampled (Cochran 1977; Krebs 1989) using 20 × 50 cm quadrats and six cover classes to estimate canopy cover for each species (Daubenmire 1959) in each microhabitat. Woody plants less than two m tall were included in the herbaceous stratum canopy estimates; the few occurrences of isolated trees were not included. The major axis of each microhabitat was divided into ten equal segments. Widths were measured beginning with a random starting point along the initial segment and at subsequent equal-segment lengths. A random point was chosen along each width to determine placement of the lower left corner of the sampling frame (20 cm side). Edge quadrats were proportionally weighted to include only the portion within the hanging garden. Total floristic composition (Daubenmire 1959, 1961), vascular plants only, was recorded during canopy cover sampling and during an additional visual search (approximately one hr) on each hanging garden. Voucher specimens for each species were collected. These were identified by B. E. Nelson, Herbarium Manager and R. L. Hartman, Curator of the Rocky Mountain Herbarium at the University of Wyoming and are deposited there and at the respective parks. Vascular plant nomenclature follows Flora of North America Editorial Committee (1993+) and Welsh et al. (2003) in that order of priority.

Floristics of each herbaceous association are described in summary stand tables by floristic criteria (Meuller-Dombois & Ellenberg 2002) and follow the definitions and analysis techniques of the U. S. National Vegetation Classification (ESA 2006). Diagnostic classes for this study were dominance determined by absolute canopy cover (Daubenmire 1959), constancy (frequency of occurrence)(Daubenmire 1952; Meuller-Dombois & Ellenberg 2002), and endemism.

Indices

Plant community diversity (heterogeneity) was measured as two separate components (Krebs 1989): species richness (McIntosh 1967) and dominance. Dominance in a community was determined by the proportion $d = N_{\text{Max}}/N_T$ (Berger & Parker 1970) where N_{Max} = number of individuals in the most abundant population and N_T = the total number of individuals in the community. Canopy coverage estimates were used as N_{Max}/N_T since both are proportional measures of species community importance.

Classification of hanging garden vegetation was based on cluster analysis of simplified Morisita (Horn 1966) community similarity indices for 73 hanging gardens calculated from species-level canopy coverage estimates of existing vegetation. An exception is the genus *Carex*. Our canopy coverage estimates for six species in this genus were combined since consistent, vegetative separation of species was not possible. These indices were placed in a community similarity matrix for cluster analysis in SYSTAT 9 (SYSTAT 1999a) using the complete linkage method (farthest neighbor) on maximum Euclidean distances between indices.

Statistics

Statistical analyses were performed with SYSTAT 9 (1999a). Plant species richness, species dominance, and hanging garden size data were analyzed by General Linear Model ANOVA. Dominance and hanging garden size were log transformed (SYSTAT 1999b) to achieve normal distributions prior to ANOVA tests. Homogeneity of variances was checked post hoc and Tukey HSD tests were used for pairwise comparisons of ANOVA results to detect significant differences between vegetation associations.

The statistical association between geologic formation and the putative herbaceous associations was described using the Pearson Chi-square goodness-of-fit test to detect the presence of an association (Loether & McTavish 1976; Wilkinson et al. 1996), and a proportional reduction in error measure (PRE), Goodman-Kruskal's lambda, to measure the strength of statistical association (Wilkinson et al. 1996). PRE statistics describe how much error is reduced in predicting the column variable when the row variable is known for association tables (Wilkinson et al. 1996).

RESULTS

Vegetation Classification

Species lists with abundance estimates for species are in Appendix I. Cluster analysis of the simplified

Morisita community similarity index (Krebs 1989) matrix classified the 73 hanging garden vascular plant communities into four associations plus one dissimilar cluster (Fig. 2): *Adiantum capillus-veneris*, *Aquilegia micrantha*, *Calamagrostis scopulorum*, and *Cirsium rydbergii* Herbaceous Associations. Euclidian distance classification thresholds (Fig. 2) ranged from 1.03 for separating the *Cirsium rydbergii* Herbaceous Association from the dissimilar group to 1.31 for separating the *C. rydbergii* and the *Adiantum capillus-veneris* Herbaceous Associations. The dissimilar cluster ($n=11$) had hanging garden communities with little similarity within the cluster (mean similarity index of 0.069) and had no plant species consistently in common.

The distribution of the four herbaceous associations across the seven geologic formations was different than expected by chance alone ($p=0.0098$), the lambda statistic indicating a 25% improvement in being able to predict the herbaceous association when the geologic formation is known (Table 1). The *A. micrantha* and *C. scopulorum* Herbaceous Associations were widespread on the Colorado Plateau (Table 1). Both were found in five parks and five sandstone geologic formations, differing in only one park and one geologic formation; the *C. scopulorum* Herbaceous Association was found on the Humbug formation omitted from Table 1. The *C. rydbergii* Herbaceous Association was found only in the central part of the Colorado Plateau: two parks and three formations (Table 1). The *A. capillus-veneris* Herbaceous Association was found on the same geologic formation as the *C. rydbergii* Herbaceous Association but was more widespread (Table 1). The *A. capillus-veneris* and *C. rydbergii* Herbaceous Associations were notably absent from the Cedar Mesa and Weber formations, which were found only in our Natural Bridges NM and Dinosaur NP study sites respectively. However, there were significant, positive statistical associations between geologic formations and herbaceous associations (Table 1). The strongest ones being between the *A. micrantha* Herbaceous Association and the Weber formation and between the *C. rydbergii* Herbaceous Association and the Navajo formation.

***Adiantum capillus-veneris* Herbaceous Association**

Floristics of the *Adiantum capillus-veneris* Herbaceous Association are defined in Table 2. The dominant species in this association was *Adiantum capillus-veneris* which covered from 32–93% of the herbaceous canopy in the 11 hanging gardens classified here (Fig. 2). Pairwise simplified Morisita community similarity indices ranged from 0.48 to 0.99. Both *A. capillus-veneris* and *Epipactis gigantea* had high constancy. *Adiantum capillus-veneris* was found in seepline and wet wall microhabitats, whereas *E. gigantea* was found in seepline microhabitats and on the upper portion of wet soil microhabitats next to vertical canyon walls with wetter seeplines. *Epipactis gigantea* and the Genus *Carex* also had high canopy cover on some hanging gardens. The vegetation was dominated by ferns, forbs, and graminoids (Table 2), but woody plants were occasionally present as isolated individuals or at the drier edges of the wet soil/rock habitats characteristic of hanging gardens.

Species diversity was relatively low in this association as shown by high dominance values, a measure of community evenness, as well as low species richness (Table 3). Dominance values were significantly higher than in *Calamagrostis scopulorum* and *Cirsium rydbergii* Herbaceous Associations (ANOVA $F = 5.02$, $p = 0.0036$; Tukey HSD $p = 0.0167$ and 0.044 respectively). Five species endemic to hanging gardens were found in this association (Table 2). The overall size of hanging gardens with this association was comparatively small (Table 3), significantly smaller than hanging gardens in the *Cirsium rydbergii* and *Calamagrostis scopulorum* Herbaceous Associations (see below) (ANOVA $F = 7.21$, $p = 0.0003$; Tukey HSD $p = 0.0003$ and 0.0266 respectively).

***Aquilegia micrantha* Herbaceous Association**

The *Aquilegia micrantha* Herbaceous Association was dominated by the hanging garden endemic *A. micrantha*, a constant species with an average canopy cover of 29% (Table 4). *Aquilegia micrantha* predominately grew on wet colluvial soil microhabitats. *Calamagrostis scopulorum* was also a constant species in this herbaceous association, but with less than 5% average cover. Pairwise simplified Morisita community similarity indices ranged from 0.28 to 1.00 for this association. With the exception of small *Pinus edulis* plants, which occurred in trace amounts of cover on 47% of these hanging gardens, woody plants rarely occurred (Table 4).

In addition to *A. micrantha*, four other hanging garden endemic species were found on these sites, but

TABLE 1. Percentage of hanging garden vegetation associations found on each of five geologic formations (row percentages). Pearson Chi Square ($\chi^2 = 34.8798$, $p = 0.0098$) and Goodman-Kruskal's lambda ($\lambda = 0.2564$ PRE) statistics indicate the existence and strength of statistical association respectively. Positive "+" and negative "-" indicate the statistical association between a geologic formation and a vegetation association. Cell Chi Square contributions are shown below cell percentages for each row followed by two letter park codes (shown in Fig. 2) to indicate geographic distribution. Observed geologic formations are Jurassic Entrada sandstone, Jurassic Navajo sandstone, Jurassic Navajo sandstone/Jurassic Kayenta formation contact zone, Permian Cedar Mesa sandstone, Pennsylvanian-Permian Weber sandstone. Vegetation associations are Adca, *Adiantum capillus-veneris*; Aqmi, *Aquilegia micrantha*; Casc, *Calamagrostis scopulorum*; Ciry, *Cirsium rydbergii*. N = 60, note that 2 geologic formations with only 1 hanging garden each were omitted from this table.

Geologic Formation	Herbaceous Vegetation Association			
	Adca	Aqmi	Casc	Ciry
Entrada n = 7	n = 11 29% 0.4002 AR	n = 17 43% 0.5211 AR	n = 19 0% - 2.4500 AR	n = 11 29% 0.4002
	35% + 2.6675 CR, GC, ZI	6% - 3.0243 GC	18% 1.4626 GC, ZI	41% + 4.8386 GC
	18% 0.0044 GC, ZI	18% 0.6852 CL, GC	53% 1.5634 CL, ZI	12% 0.4001 GC
	0% 1.4667	50% 1.3255 NB	50% 0.5143 NB	0% 1.4667
Navajo n = 17	0%	67% + 4.6676	33% 0.0071	0% 1.6500
	0% 1.6500	DI	DI	

at lower constancy (Table 4). This association was significantly less species rich than the *C. scopulorum* and *C. rydbergii* Herbaceous Associations (see below) (ANOVA $F = 3.79$, $p = 0.015$; Tukey HSD $p = 0.0248$ and 0.0372 respectively). Dominance values averaged 0.59, not significantly different than the other three associations (Table 3). Hanging gardens in this association were also significantly smaller in average size than hanging gardens classified in the *C. rydbergii* association (see below) (ANOVA $F = 7.21$, $p = 0.0003$; Tukey HSD $p = 0.0009$, Table 3).

***Calamagrostis scopulorum* Herbaceous Association**

Floristics of the *Calamagrostis scopulorum* Herbaceous Association are defined in Table 5. As the dominant species, *C. scopulorum* had an average cover of 31% and a range of 13–66% (Table 5). *Calamagrostis scopulorum* grew in larger clumps on wet colluvial soil microhabitats and as smaller patches on seepline and wet wall microhabitats. Several *Carex* species also occurred in these hanging gardens (Table 5). The hanging garden endemic *A. micrantha* was moderately constant and ranged up to 11% total cover. Simplified Moristia community similarity indices ranged from 0.27 to 0.99 among the 23 hanging gardens classified into this association.

Species diversity in this association was relatively high as shown by high species richness and low dominance (Table 3). This association was significantly richer than the *A. micrantha* Herbaceous Association (ANOVA $F = 3.79$, $p = 0.0003$; Tukey HSD $p = 0.0248$), and its dominance values were significantly lower than the *A. capillus-veneris* Herbaceous Association (ANOVA $F = 5.02$, $p = 0.0036$; Tukey HSD $p = 0.0167$). Three hanging garden endemic taxa were found on the 23 hanging gardens classified in this association (Table 5). The *C. scopulorum* Herbaceous Association tended to contain large hanging gardens (Table 3), significantly larger than hanging gardens in the *A. capillus-veneris* Herbaceous Association (ANOVA $F = 7.21$, $p = 0.0003$; Tukey HSD $p = 0.027$).




FIG. 2. Cluster tree showing four hanging garden herbaceous vegetation associations and a dissimilar cluster based on cluster analysis of simplified Moristia community similarity indices. Names refer to 73 individual hanging garden plant communities. Two letter codes following hanging garden names refer to individual parks: AR = Arches (NP); CL = Canyonlands (NP); GC = Glen Canyon (NRA); ZI = Zion (NP); CR = Capitol Reef (NP); NB = Natural Bridges (NM); DI = Dinosaur (NP).

TABLE 2. Stand table for the *Adiantum capillus-veneris* Herbaceous Association showing canopy cover, diagnostic classes, and constancy for all species with a constancy ≥ 0.40 and/or species endemic to hanging gardens. Constant species are defined as constancy ≥ 0.60 , and "t" is defined as less than 0.5 % canopy cover. N = 11.

Species	Diagnostic class	Constancy	Average % cover	Minimum % cover	Maximum % cover
<i>Adiantum capillus-veneris</i>	dominant, constant	1.00	57	32	93
<i>Epipactis gigantea</i>	constant	0.82	2	0	16
<i>Aquilegia micrantha</i>	endemic	0.27	1	0	8
<i>Cirsium rydbergii</i>	endemic	0.36	2	0	8
<i>Mimulus eastwoodiae</i>	endemic	0.55	t	0	2
<i>Primula specuicola</i>	endemic	0.27	t	0	2
<i>Zigadenus vaginatus</i>	endemic	0.09	t	0	t
<i>Carex</i> sp.		0.45	3	0	18
<i>Petrophytum caespitosum</i>		0.45	t	0	2

TABLE 3. Mean values (± 1 SE) for hanging garden size, species richness, and dominance of four hanging garden herbaceous associations. Also shown are number of sites (N) and number of hanging garden endemic plants species found (HGE) in each association. Values followed by the same letter within each column do not differ at P<0.05 in Tukey's HSD post hoc tests.

Hanging garden vegetation association	Size m ²	Species Richness	Dominance	N	HGE
<i>Adiantum capillus-veneris</i>	68 \pm 20 ^a	14 \pm 2 ^{ab}	0.71 \pm 0.05 ^a	11	5
<i>Aquilegia micrantha</i>	167 \pm 45 ^{ab}	12 \pm 1 ^a	0.59 \pm 0.06 ^{ab}	17	5
<i>Calamagrostis scopulorum</i>	314 \pm 80 ^{bc}	18 \pm 2 ^b	0.48 \pm 0.04 ^b	23	3
<i>Cirsium rydbergii</i>	587 \pm 168 ^c	18 \pm 2 ^b	0.41 \pm 0.03 ^b	11	5

TABLE 4. Stand table for the *Aquilegia micrantha* Herbaceous Association showing canopy cover, diagnostic classes, and constancy for all species with a constancy ≥ 0.40 and/or species endemic to hanging gardens. Constant species are defined as constancy ≥ 0.60 , and "t" is defined as less than 0.5 % canopy cover. N = 17.

Species	Diagnostic class	Constancy	Average % cover	Minimum % cover	Maximum % cover
<i>Aquilegia micrantha</i> endemic	dominant, constant,	1.00	29	9	54
<i>Calamagrostis scopulorum</i>	Constant	0.82	4	0	32
<i>Cirsium rydbergii</i>	Endemic	0.24	1	0	8
<i>Mimulus eastwoodiae</i>	Endemic	0.35	1	0	11
<i>Primula specuicola</i>	Endemic	0.24	t	0	2
<i>Zigadenus vaginatus</i>	Endemic	0.35	2	0	19
<i>Carex</i> sp.		0.41	2	0	10
<i>Pinus edulis</i>		0.47	t	0	t

***Cirsium rydbergii* Herbaceous Association**

The hanging garden endemic *Cirsium rydbergii* dominated this association with an average of 23% canopy coverage (Table 6). These hanging gardens also had nine additional constant species (Table 6). Two of these were co-dominants, *A. capillus-veneris* and *Schyzachrium scoparium*, and three were endemic to hanging garden habitats: *A. micrantha*, *Mimulus eastwoodiae*, and *Primula specuicola*. One additional hanging garden endemic species was also found at low constancy in these hanging gardens: *Zigadenus vaginatus*. *Cirsium rydbergii* and *A. micrantha* were found throughout the wet colluvial soil microhabitat and *Z. vaginatus* was often

TABLE 5. Stand table for the *Calamagrostis scopulorum* Herbaceous Association showing canopy cover, diagnostic classes, and constancy for all species with a constancy ≥ 0.40 and/or species endemic to hanging gardens. Constant species are defined as constancy ≥ 0.60 , and "t" is defined as less than 0.5 % canopy cover. N = 23.

	Diagnostic class	Constancy	Average % cover	Minimum % cover	Maximum % cover
<i>Calamagrostis scopulorum</i>	dominant	1.00	31	13	66
<i>Carex</i> sp.	constant	0.65	3	0	20
<i>Aquilegia micrantha</i>	endemic	0.43	2	0	11
<i>Zigadenus vaginatus</i>	endemic	0.22	1	0	14
<i>Mimulus eastwoodiae</i>	endemic	0.22	t	0	t
<i>Adiantum capillus-veneris</i>		0.57	4	0	30
<i>Epipactis gigantea</i>		0.48	1	0	16
<i>Maianthemum stellatum</i>		0.57	3	0	20
<i>Toxicodendron rydbergii</i>		0.48	t	0	11

TABLE 6. Stand table for the *Cirsium rydbergii* Herbaceous Association showing canopy cover, diagnostic classes, and constancy for all species with a constancy ≥ 0.40 and/or species endemic to hanging gardens. Constant species are defined as constancy ≥ 0.60 , and "t" is defined as less than 0.5 % canopy cover. N = 11.

Species	Diagnostic class	Constancy	Average % cover	Minimum % cover	Maximum % cover
<i>Cirsium rydbergii</i>	dominant, constant, endemic	1.00	23	1	48
<i>Adiantum capillus-veneris</i>	co-dominant, constant	0.91	10	0	23
<i>Schizachyrium scoparium</i>	co-dominant, constant	0.64	15	0	50
<i>Carex</i> sp.	constant	0.91	7	0	19
<i>Aquilegia micrantha</i>	constant, endemic	0.82	3	0	14
<i>Primula specuicola</i>	constant, endemic	0.91	1	0	3
<i>Mimulus eastwoodiae</i>	constant, endemic	0.64	3	0	8
<i>Calamagrostis scopulorum</i>	constant	0.64	2	0	13
<i>Petrophytum caespitosum</i>	constant	0.64	2	0	12
<i>Epipactis gigantea</i>	constant	0.73	1	0	5
<i>Zigadenus vaginatus</i>	endemic	0.27	1	0	13
<i>Castilleja linearifolia</i>		0.45	t	0	2
<i>Dichanthelium acuminatum</i>		0.55	4	0	26

found in the upper portions of the wet colluvial soil microhabitat next to canyon walls. *Mimulus eastwoodiae* and *P. specuicola* were often attached directly to vertical or inverted, wet rock surfaces. Simplified Morisita community similarity indices ranged from 0.06 to 0.90 among the 11 hanging gardens in this association.

Species richness was relatively high (Table 3), significantly higher than in the *A. micrantha* Herbaceous Association (ANOVA F = 3.79 p = 0.015; Tukey HSD p = 0.0372). Dominance values were low (Table 3), significantly lower than in the *A. capillus-veneris* Herbaceous Association (ANOVA F = 5.02, p = 0.0036, Tukey HSD p = 0.0044). Similar to the *C. scopulorum* Herbaceous Association, this association occurred on large hanging gardens; the average size was significantly larger than in the *A. capillus-veneris* and *A. micrantha* Herbaceous Associations (ANOVA F = 7.21, p = 0.0003; Tukey HSD p = 0.0003 and 0.0009 respectively).

DISCUSSION

The *A. capillus-veneris* and *A. micrantha* Herbaceous Associations tend to grow on smaller hanging gardens that are less diverse; i.e., have low species richness and high dominance values (Table 3). The *A. capillus-veneris* Herbaceous Association is dominated by relatively dry seepline microhabitats and by rhizomatous

stands of *A. capillus-veneris* which grow on and near narrow seeplines formed in the Navajo sandstone. The *A. micrantha* association is dominated by *A. micrantha* which grows on the less wet colluvial soil microhabitats, especially on Cedar Mesa and Weber sandstone formations. Note that these two geologic formations and the Entrada formation were found in only one park each and thus also act as surrogates for geography. In contrast, the hanging gardens with *C. scopulorum* and *C. rydbergii* Herbaceous Associations tended to be larger and, by implication, wetter: i.e., large wet colluvial soil microhabitats. They also tend to be more diverse: i.e., more species rich and low species dominance (Table 3).

The dissimilar cluster (Fig. 2) may represent a collection of unique plant communities which are not part of any herbaceous association. Alternatively, with further sampling on the Colorado Plateau, we may find that some of the hanging gardens within this cluster do represent undiscovered herbaceous associations. Further research is needed.

Neither Tuhy and MacMahon (1988) nor Romme et al. (1993) attempted to classify the vegetation of individual hanging gardens but rather placed all hanging gardens into one vegetation type. We found no species that all hanging gardens had in common (much less a common dominant) which precludes a single hanging garden herbaceous association. The alliance name on NatureServe (2006), *Aquilegia micrantha saturated hanging garden herbaceous vegetation*, would obviously work for the *A. micrantha* Herbaceous Association but not for the remaining three associations since neither *A. micrantha* nor any other species was constant or dominant across all four associations described in this paper (Tables 2, 4, 5, 6). Four separate alliances would seem to be necessary in spite of a common distinct habitat.

NatureServe (2006) also lists two hanging garden herbaceous associations inside our study area: *A. micrantha - M. eastwoodiae* and *A. micrantha - C. scopulorum* Herbaceous Vegetation, each association being named for its dominant species. *Aquilegia micrantha* and *C. scopulorum* are shown as characteristic species for both associations, but no data are shown for canopy coverage or constancy. In addition, no publications are cited that have this type of data and the link to VegBank (2006) indicates that no plot-observations are available, precluding further comparison. Woodbury's (1933) *fern-columbine* assocs in Zion NP hanging gardens is habitat-based and seems to overlap the *A. capillus-veneris* and *C. scopulorum* Herbaceous Associations described in this paper.

Outside of Woodbury's (1933) study in Zion NP, there are no previously published studies that describe hanging garden associations. Most inselberg studies also classify vegetation by habitat (e.g., Burbank & Platt 1964), but we found one with a phytosociological focus. Sarthou and Villiers (1998) conducted a regional vegetation study on three inselbergs in French Giana using relevé quadrats and tabular analysis. In spite of different techniques, their results were comparable to our study. They found six vegetation associations versus our four, and they found two French Galian inselberg endemics versus our five hanging garden endemics. More interestingly, their most widespread vegetation association (with three subassociations) was dominated by *Pepinietum geyskesii*, a French Galian inselberg endemic. In our study, two vegetation associations were dominated by hanging garden endemics: the *A. micrantha* and the *C. rydbergii* Herbaceous Associations (Tables 4 & 6). Both studies illustrate the concept of insular vegetation on continental islands at a regional scale. Our study also looked at the regional distribution of these four herbaceous associations and found that each has a unique distribution on the Colorado Plateau (Table 1).

APPENDIX 1

Vascular plant species lists and species richness (R) for each hanging garden sampled. Canopy coverage estimates (0-100%) are shown to the right of the scientific name for species which fell within community sampling quadrats with T indicating less than 0.5%; no estimates were made for taxa not falling within sampling quadrats: **ARCH** = Arches NP, **CANY** = Canyonlands NP, **CARE** = Capitol Reef NP, **DINO** = Dinosaur NM, **GLCA** = Glen Canyon NRA, **NABR** = Natural Bridges NM, **ZION** = Zion NP.

<u>ARCH</u> Backarch HG R = 24	<i>Cirsium rydbergii</i> 7	<i>Heterotheca villosa</i> var. minor 1	Cyperaceae
Anacardiaceae	<i>Pseudognaphalium microcephalum</i> T	<i>Solidago velutina</i> subsp. <i>sparsiflora</i>	Euphorbiaceae
<i>Toxicodendron rydbergii</i> 7			<i>Euphorbia brachycera</i> T
Asteraceae			

Poaceae	
<i>Calamagrostis scopulorum</i>	
66	
<i>Phragmites australis</i>	
Ranunculaceae	
<i>Aquilegia micrantha</i>	10
Rhamnaceae	
<i>Rhamnus betulifolia</i>	
Rosaceae	
<i>Rosa sp.</i>	
Scrophulariaceae	
<i>Castilleja linariifolia</i>	
<i>Mimulus eastwoodiae</i>	
<u>CANY Northface HG R = 13</u>	
Asteraceae	
<i>Cirsium rydbergii</i>	8
Betulaceae	
<i>Betula occidentalis</i>	
Cornaceae	
<i>Cornus sericea</i>	
Cyperaceae	
<i>Carex sp.</i>	
Fagaceae	
<i>Quercus gambelii</i>	
Liliaceae	
<i>Maianthemum stellatum</i>	
<i>Zigadenus vaginatus</i>	
Orchidaceae	
<i>Platantherera zothecina</i>	
Poaceae	
<i>Calamagrostis scopulorum</i>	
Ranunculaceae	
<i>Aquilegia micrantha</i>	54
Rosaceae	
<i>Amelanchier sp.</i>	
<i>Rosa sp.</i>	
Scrophulariaceae	
<i>Mimulus eastwoodiae</i>	
<u>CANY Raven HG R = 16</u>	
Anacardiaceae	
<i>Rhus aromatica</i> var. <i>simplicifolia</i>	
<i>Toxicodendron rydbergii</i>	
Apocynaceae	
<i>Apocynum cannabinum</i> T	
Asteraceae	
<i>Cirsium arizonicum</i> var. <i>bipinnatum</i>	
Berberidaceae	
<i>Berberis fendleri</i> 3	
Cyperaceae	
<i>Carex aurea</i> 10	
Orchidaceae	
<i>Platantherera zothecina</i>	
Pinaceae	
<i>Pinus edulis</i>	
<u>CANY Raven HG R = 16</u>	
Poaceae	
<i>Calamagrostis scopulorum</i>	
Ranunculaceae	
<i>Aquilegia micrantha</i>	54
Rosaceae	
<i>Amelanchier sp.</i>	
<i>Rosa sp.</i>	
Scrophulariaceae	
<i>Mimulus eastwoodiae</i>	
<u>CANY Raven HG R = 16</u>	
Anacardiaceae	
<i>Rhus aromatica</i> var. <i>simplicifolia</i>	
<i>Toxicodendron rydbergii</i>	
Apocynaceae	
<i>Apocynum cannabinum</i> T	
Asteraceae	
<i>Cirsium arizonicum</i> var. <i>bipinnatum</i>	
Berberidaceae	
<i>Berberis fendleri</i> 3	
Cyperaceae	
<i>Carex aurea</i> 10	
Orchidaceae	
<i>Platantherera zothecina</i>	
Pinaceae	
<i>Pinus edulis</i> T	

Poaceae	
<i>Calamagrostis scopulorum</i>	
48	
Ranunculaceae	
<i>Aquilegia micrantha</i>	10
Rhamnaceae	
<i>Rhamnus betulifolia</i>	3
Rosaceae	
<i>Holodiscus dumosus</i>	
<i>Rosa sp.</i>	
Rubiaceae	
<i>Galium sp.</i>	
Scrophulariaceae	
<i>Castilleja linariifolia</i>	
<i>Mimulus eastwoodiae</i>	
<u>CANY Gate HG R = 12</u>	
Anacardiaceae	
<i>Toxicodendron rydbergii</i>	
Asteraceae	
<i>Cirsium arizonicum</i> var. <i>bipinnatum</i>	2
Cyperaceae	
<i>Carex aurea</i>	9
Orchidaceae	
<i>Platantherera zothecina</i>	
Pinaceae	
<i>Pinus edulis</i>	
Poaceae	
<i>Calamagrostis scopulorum</i>	
31	
<i>Muhlenbergia thurberi</i>	
<i>Piptatherum micranthum</i>	
Ranunculaceae	
<i>Aquilegia micrantha</i>	37
Rosaceae	
<i>Amelanchier sp.</i>	
<i>Cercocarpus sp.</i>	
<i>Rosa sp.</i>	
<u>CANY Rocky HG R=7</u>	
Asteraceae	
<i>Cirsium arizonicum</i> var. <i>bipinnatum</i>	8
<i>Erigeron sparsifolius</i>	1
Pinaceae	
<i>Pinus edulis</i>	
Poaceae	
<i>Calamagrostis scopulorum</i>	
21	
Ranunculaceae	
<i>Aquilegia micrantha</i>	6
Santalaceae	
<i>Comandra umbellata</i> var. <i>pallida</i>	4
Scrophulariaceae	
<i>Mimulus eastwoodiae</i>	
<u>CARE Sidewall HG R = 12</u>	
Anacardiaceae	
<i>Toxicodendron rydbergii</i>	19
Asteraceae	
<i>Cirsium arizonicum</i> var. <i>bipinnatum</i>	4
<i>Heterotheca villosa</i> var. <i>minor</i>	
<i>Sonchus sp.</i>	
Equisetaceae	
<i>Equisetum laevigatum</i>	1
Oleaceae	
<i>Fraxinus anomala</i>	
Orchidaceae	
<i>Epipactis gigantea</i>	
Poaceae	
<i>Elymus canadensis</i> T	
<i>Dichanthelium</i>	
<i>acuminatum</i>	7
Pteridaceae	
<i>Adiantum capillus-veneris</i>	56
Scrophulariaceae	
<i>Castilleja scabrida</i>	
Ulmaceae	
<i>Celtis reticulata</i>	5
<u>CARE Horseshoe HG R = 8</u>	
Apocynaceae	
<i>Apocynum cannabinum</i>	
Asteraceae	
<i>Brickellia longifolia</i> var. <i>longifolia</i>	
Orchidaceae	
<i>Epipactis gigantea</i> T	
Oleaceae	
<i>Fraxinus anomala</i>	
Poaceae	
<i>Elymus canadensis</i>	
<i>Elymus trachycaulus</i>	
Pteridaceae	
<i>Adiantum capillus-veneris</i>	95
Scrophulariaceae	
<i>Mimulus eastwoodiae</i> T	
<u>DINO Ponderosa HG R = 17</u>	
Asteraceae	
<i>Cirsium ownbeyi</i>	2
<i>Erigeron nematophyllum</i>	
<i>Heterotheca villosa</i> var. <i>minor</i> T	
Cupressaceae	
<i>Juniperus osteosperma</i>	
Hydrangiaceae	
<i>Fendlerella utahensis</i>	
Liliaceae	
<i>Zigadenus vaginatus</i>	14
Pinaceae	
<i>Pinus edulis</i>	
Poaceae	
<i>Calamagrostis scopulorum</i>	
19	
<i>Muhlenbergia thurberi</i>	
<i>Piptatherum micranthum</i>	
<i>Poa fendleriana</i>	
Pteridaceae	
<i>Pellaea glabella</i> subsp. <i>simplex</i>	
Ranunculaceae	
<i>Aquilegia micrantha</i>	1
Rosaceae	
<i>Amelanchier sp.</i>	
<i>Petrosphytum caespitosum</i>	
Rubiaceae	
<i>Galium sp.</i>	
Scrophulariaceae	
<i>Castilleja linariifolia</i>	

DINO Yampa HG R = 18	Primulaceae	Ranunculaceae	Ranunculaceae
Asteraceae	<i>Dodecatheon pulchellum</i> var. <i>pulchellum</i>	<i>Aquilegia micrantha</i> 35	<i>Aquilegia micrantha</i> 3
<i>Cirsium ownbeyi</i> T	Ranunculaceae	Rosaceae	<i>Clematis ligusticifolia</i> 34
<i>Erigeron nematophyllum</i> 6	<i>Clematis ligusticifolia</i>	Rosaceae	
<i>Heterotheca villosa</i> var. minor 2	Rubiaceae	<i>Cercocarpus intricatus</i> T	<i>Cercocarpus intricatus</i>
<i>Packera multilobata</i>	<i>Galium</i> sp.	Salicaceae	<i>Petrophytum caespitosum</i>
<i>Taraxacum officinale</i>	Salicaceae	<i>Populus deltoides</i> subsp. <i>wislizenii</i>	Scrophulariaceae
Caprifoliaceae	<i>Salix</i> sp.	DINO Rimrock HG R = 9	<i>Castilleja linariifolia</i>
<i>Symphoricarpos</i> sp.	DINO Snow HG R = 8	Asteraceae	DINO Marbles HG R = 16
Hydrangiaceae	Anacardiaceae	<i>Erigeron nematophyllum</i>	Asteraceae
<i>Fendlerella utahensis</i> 9	<i>Rhus aromatica</i> var. <i>trilobata</i> 2	<i>Heterotheca villosa</i> var. minor	<i>Erigeron nematophyllum</i> 18
Liliaceae	Cupressaceae	Liliaceae	<i>Heterotheca villosa</i> var. minor 2
<i>Zigadenus vaginatus</i> 1	<i>Juniperus osteosperma</i>	<i>Zigadenus vaginatus</i> 2	<i>Xanthista grindeloides</i> T
Linaceae	Loasaceae	Pinaceae	<i>Taraxacum officinale</i> T
<i>Linum lewisii</i>	<i>Mentzelia multicaulis</i> 2	<i>Pinus edulis</i>	Berberidaceae
Poaceae	Orchidaceae	Poaceae	<i>Berberis repens</i>
<i>Calamagrostis scopulorum</i>	<i>Epipactis gigantea</i> 19	<i>Calamagrostis scopulorum</i>	Boraginaceae
<i>Elymus repens</i> 1	Pinaceae	Ranunculaceae	<i>Cryptantha</i> sp. 1
<i>Hesperostipa comata</i> var. comata 1	<i>Pinus ponderosa</i>	<i>Aquilegia micrantha</i> 19	Caprifoliaceae
Pteridaceae	Poaceae	Rosaceae	<i>Symphoricarpos</i> sp. 1
<i>Pellaea glabella</i> subsp. <i>simplex</i>	<i>Calamagrostis scopulorum</i> 19	<i>Cercocarpus intricatus</i>	Hydrangiaceae
Ranunculaceae	Primulaceae	<i>Petrophytum caespitosum</i>	<i>Fendlerella utahensis</i> 2
<i>Aquilegia micrantha</i> 2	<i>Dodecatheon pulchellum</i> var. <i>pulchellum</i> 12	Scrophulariaceae	Pinaceae
Rosaceae	Ranunculaceae	<i>Castilleja lineariifolia</i>	<i>Pinus edulis</i> T
<i>Cercocarpus intricatus</i> 7	<i>Aquilegia micrantha</i> 15	DINO Signature HG R = 19	Poaceae
<i>Holodiscus dumosus</i> T	DINO Bench HG R = 17	Asteraceae	<i>Achnatherum hymenoides</i> T
<i>Petrophytum caespitosum</i> 7	Asteraceae	<i>Ericameria nauseosa</i>	Pteridaceae
Scrophulariaceae	<i>Achillea millefolium</i>	<i>Cirsium ownbeyi</i> 4	<i>Pellaea glabella</i> subsp. <i>simplex</i>
<i>Castilleja linariifolia</i> T	<i>Ericameria nauseosa</i>	<i>Heterotheca villosa</i> var. minor	Ranunculaceae
DINO Bull HG R = 16	<i>Cirsium ownbeyi</i> 2	Brassicaceae	<i>Aquilegia micrantha</i> 1
Aceraceae	<i>Cirsium ownbeyi</i> 2	<i>Lepidium montanum</i> var. <i>jonesii</i>	Rosaceae
<i>Acer negundo</i> 2	<i>Erigeron nematophyllum</i>	Cyperaceae	<i>Cercocarpus intricatus</i> 8
Anacardiaceae	<i>Heterotheca villosa</i> var. minor	<i>Carex aurea</i> 2	<i>Holodiscus dumosus</i> 3
<i>Rhus aromatica</i> var. <i>trilobata</i> 1	Cupressaceae	Euphorbiaceae	<i>Petrorhynchus caespitosum</i> 5
<i>Toxicodendron rydbergii</i> 2	<i>Juniperus osteosperma</i>	<i>Euphorbia brachycera</i>	Scrophulariaceae
Asteraceae	Cyperaceae	Liliaceae	<i>Castilleja</i> sp. T
<i>Achillea millefolium</i> T	<i>Carex aurea</i> 2	<i>Zigadenus vaginatus</i> 2	DINO Buzz HG R = 7
<i>Taraxacum officinale</i>	Ephedraceae	Orchidaceae	Asteraceae
Betulaceae	<i>Ephedra viridis</i>	<i>Epipactis gigantea</i> 16	<i>Artemisia ludoviciana</i> subsp. <i>ludoviciana</i> 6
<i>Betula occidentalis</i>	Hydrangiaceae	Poaceae	Cyperaceae
Caprifoliaceae	<i>Fendlerella utahensis</i> 1	<i>Calamagrostis scopulorum</i> 37	<i>Carex aurea</i> 1
<i>Symphoricarpos</i> sp. 2	Liliaceae	<i>Muhlenbergia thurberi</i>	Fabaceae
Cornaceae	<i>Zigadenus vaginatus</i> 7	<i>Dichanthelium</i> <i>acuminatum</i> T	<i>Melilotus officinalis</i>
<i>Cornus sericea</i>	Pinaceae	Pteridaceae	Poaceae
Liliaceae	<i>Pinus edulis</i>	<i>Adiantum capillus-veneris</i> T	<i>Agrostis stolonifera</i> 6
<i>Maianthemum stellatum</i> 7	Poaceae	<i>Pellaea glabella</i> subsp. <i>simplex</i>	<i>Calamagrostis scopulorum</i> 2
Orchidaceae	<i>Calamagrostis scopulorum</i>	Primulaceae	Primulaceae
<i>Platanthera zothecina</i> 7	<i>Elymus elymoides</i> var. <i>brevifolius</i>	<i>Dodecatheon pulchellum</i> var. <i>pulchellum</i>	<i>Dodecatheon pulchellum</i> var. <i>pulchellum</i> 2
Pinaceae	Polypodiaceae		Ranunculaceae
<i>Pseudotsuga menziesii</i>	<i>Pellaea glabella</i> subsp. <i>simplex</i>		<i>Aquilegia micrantha</i> 37
Poaceae			
<i>Calamagrostis scopulorum</i>			

<u>DINO Redrock HG R = 18</u>	Lamiaceae <i>Mentha arvensis</i> 2	Santalaceae <i>Comandra umbellata</i> var. <i>pallida</i> 2	Primulaceae <i>Primula specuicola</i> 1
Asteraceae <i>Toxicodendron rydbergii</i> <i>Artemisia ludoviciana</i> subsp. <i>ludoviciana</i> 2 <i>Heterotheca villosa</i> var. <i>minor</i> 4 <i>Taraxacum officinale</i> 4	Liliaceae <i>Maianthemum stellatum</i> T	Scrophulariaceae <i>Castilleja linariifolia</i>	Ranunculaceae <i>Aquilegia micrantha</i> 18
Brassicaceae <i>Lepidium latifolium</i> 15	Onagraceae <i>Epilobium</i> sp. <i>Oenothera caespitosa</i> T	<u>GLCA Camp HG R = 19</u>	Rosaceae <i>Petrosphytum caespitosum</i> 5
Cyperaceae <i>Carex aurea</i> 5	Poaceae <i>Calamagrostis scopulorum</i> 28 <i>Elymus trachycaulus</i> 1 <i>Glyceria striata</i> T <i>Koeleria macrantha</i> <i>Phragmites australis</i> 8 <i>Poa pratensis</i> <i>Pseudoroegneria spicata</i>	Apocynaceae <i>Apocynum cannabinum</i> 3	Scrophulariaceae <i>Mimulus eastwoodiae</i> 1
Fabaceae <i>Melilotus albus</i> <i>Melilotus officinalis</i>	Polygonaceae <i>Erigonum corymbosum</i> var. <i>corymbosum</i>	Asteraceae <i>Artemisia ludoviciana</i> subsp. <i>mexicana</i> <i>Brickellia longifolia</i> var. <i>longifolia</i> T <i>Taraxacum officinale</i>	Vitaceae <i>Parthenocissus vitacea</i> 2
Liliaceae <i>Maianthemum stellatum</i>	Ranunculaceae <i>Aquilegia micrantha</i> 1 <i>Clematis ligusticifolia</i> 12	Berberidaceae <i>Berberis repens</i>	<u>GLCA Corner HG R = 13</u>
Orchidaceae <i>Platanthera zothecina</i> 11	Rosaceae <i>Rosa woodsii</i> 6	Betulaceae <i>Ostrya knowltonii</i>	Agavaceae <i>Yucca</i> sp. T
Poaceae <i>Agrostis stolonifera</i> <i>Calamagrostis scopulorum</i> 2 <i>Muhlenbergia andina</i> <i>Poa pratensis</i> 2	Violaceae <i>Viola</i> sp.	Cyperaceae <i>Carex aurea</i> 10	Anacardiaceae <i>Rhus aromatica</i> var. <i>simplicifolia</i>
Ranunculaceae <i>Aquilegia micrantha</i> 18 <i>Clematis ligusticifolia</i>	<u>DINO Ely HG R = 17</u>	Fabaceae <i>Cercis occidentalis</i> var. <i>orbiculata</i> 3	Asteraceae <i>Artemisia ludoviciana</i> subsp. <i>ludoviciana</i> <i>Cirsium rydbergii</i> 2
Rosaceae <i>Petrosphytum caespitosum</i> 7	Asteraceae <i>Crepis runcinata</i> var. <i>glaucoides</i> <i>Erigeron nematophyllum</i>	Fagaceae <i>Quercus gambelii</i>	Cyperaceae <i>Carex aurea</i>
Ulmaceae <i>Celtis reticulata</i> 4	Betulaceae <i>Betula occidentalis</i>	Orchidaceae <i>Platanthera zothecina</i> 1	Fagaceae <i>Quercus gambelii</i>
<u>DINO Limestone HG R = 29</u>	Euphorbiaceae <i>Euphorbia brachycera</i> T	Poaceae <i>Calamagrostis scopulorum</i> 4	Orchidaceae <i>Epipactis gigantea</i>
Apocynaceae <i>Apocynum cannabinum</i>	Hydrangiaceae <i>Fendlerella utahensis</i>	Pteridaceae <i>Polypogon interruptus</i>	Poaceae <i>Calamagrostis scopulorum</i> 14
Asclepiadaceae <i>Asclepias speciosa</i>	Loasaceae <i>Mentzelia</i> sp. 3	Pteridaceae <i>Polypogon viridis</i>	Pteridaceae <i>Adiantum capillus-veneris</i> 54
Asteraceae <i>Artemisia ludoviciana</i> subsp. <i>ludoviciana</i> 2	Pinaceae <i>Pinus edulis</i>	Ranunculaceae <i>Aquilegia micrantha</i> 9	Rosaceae <i>Petrosphytum caespitosum</i>
<i>Ericameria nauseosa</i> <i>Cirsium ownbeyi</i> 15 <i>Tragopogon dubius</i> T	Poaceae <i>Calamagrostis scopulorum</i> 4	Rhamnaceae <i>Clematis ligusticifolia</i>	Scrophulariaceae <i>Mimulus eastwoodiae</i>
Brassicaceae <i>Lepidium montanum</i> var. <i>jonesii</i>	Pteridaceae <i>Muhlenbergia thurberi</i> 1	Rosaceae <i>Rhamnus betulifolia</i>	Ulmaceae <i>Celtis reticulata</i>
Cyperaceae <i>Carex parryana</i> 2	Primulaceae <i>Achnatherum hymenoides</i> 1	Scrophulariaceae <i>Rubus neomexicanus</i> 3	Vitaceae <i>Parthenocissus vitacea</i> 4
<i>Carex aquatilis</i> var. <i>aquatilis</i>	Pteridaceae <i>Pellaea glabella</i> subsp. <i>simplex</i> 4	<u>GLCA Channel HG R = 11</u>	<u>GLCA Crossbed HG R = 23</u>
<i>Carex aurea</i>	Primulaceae <i>Dodecatheon pulchellum</i> var. <i>pulchellum</i> 1	Anacardiaceae <i>Toxicodendron rydbergii</i> T	Agavaceae <i>Yucca</i> sp. 1
Equisetaceae <i>Equisetum laevigatum</i> 1	Ranunculaceae <i>Aquilegia micrantha</i> 13	Asteraceae <i>Cirsium rydbergii</i> 1	Anacardiaceae <i>Rhus aromatica</i> var. <i>simplicifolia</i>
Fabaceae <i>Melilotus officinalis</i> T	Rosaceae <i>Cercocarpus intricatus</i>	Cyperaceae <i>Carex</i> sp. T	Asteraceae <i>Brickellia longifolia</i> var. <i>longifolia</i> 1
Juncaceae <i>Juncus ensifolius</i> var. <i>montanus</i>	<i>Petrosphytum caespitosum</i> 7	Fagaceae <i>Quercus gambelii</i> 2	<i>Cirsium rydbergii</i> 11
		Poaceae <i>Calamagrostis scopulorum</i> 6	<i>Erigeron sparsifolius</i>
		Pteridaceae <i>Adiantum capillus-veneris</i> 7	<i>Tetraneurus ivesiana</i>
			<i>Gutierrezia sarothrae</i> T
			<i>Solidago velutina</i> subsp. <i>sparsiflora</i> 2
			Cyperaceae <i>Carex curatorum</i> 3

Loasaceae	Rhamnaceae	Poaceae	Scrophulariaceae
<i>Mentzelia cronequistii</i>	<i>Rhamnus betulifolia</i> 9	<i>Muhlenbergia</i> sp. T	<i>Castilleja linariifolia</i>
Oleaceae	Rosaceae	Pteridaceae	<i>Mimulus eastwoodiae</i> T
<i>Fraxinus anomala</i>	<i>Petrophytum caespitosum</i> 4	<i>Adiantum capillus-veneris</i> 93	Ulmaceae
Orchidaceae	Salicaceae	Ranunculaceae	<i>Celtis reticulata</i>
<i>Epipactis gigantea</i>	<i>Salix ligulifolia</i> 8	<i>Aquilegia micrantha</i>	Vitaceae
Poaceae	Scrophulariaceae	Rhamnaceae	<i>Parthenocissus vitacea</i> 3
<i>Andropogon glomeratus</i> var. <i>scabriglumis</i>	<i>Castilleja linariifolia</i> 1	<i>Rhamnus betulifolia</i>	<u>GLCA Hawk HG R = 12</u>
<i>Calamagrostis scopulorum</i> 2	Ulmaceae	Rosaceae	Asteraceae
<i>Dichanthelium acuminatum</i>	<i>Celtis reticulata</i>	<i>Petrophytum caespitosum</i>	<i>Brickellia longifolia</i> var. <i>longifolia</i>
<i>Schizachyrium scoparium</i> 26	<u>GLCA Fence HG R = 19</u>	Ulmaceae	<i>Cirsium rydbergii</i> 36
Polygonaceae	Anacardiaceae	Asteraceae	Cyperaceae
<i>Eriogonum corymbosum</i> var. <i>corymbosum</i> T	<i>Rhus aromatica</i> var. <i>trilobata</i>	<i>Baccharis emoryi</i> 7	<i>Carex aurea</i> 4
Pteridaceae	<i>Toxicodendron rydbergii</i> 1	<i>Cirsium rydbergii</i>	Fagaceae
<i>Adiantum capillus-veneris</i> 2	Asteraceae	<i>Erigeron sparsifolius</i>	<i>Quercus gambelii</i> T
Primulaceae	<i>Cirsium sp.</i> T	Brassicaceae	Poaceae
<i>Primula specuicola</i> 1	<i>Heterotheca villosa</i> var. <i>minor</i> 2	<i>Thelypodium integrifolium</i>	<i>Calamagrostis scopulorum</i> 1
Rhamnaceae	<i>Solidago canadensis</i>	Cyperaceae	<i>Muhlenbergia andina</i>
<i>Rhamnus betulifolia</i>	<i>Solidago velutina</i> subsp. <i>sparsiflora</i> 1	<i>Carex aurea</i>	<i>Polypogon viridis</i> T
Rosaceae	Campanulaceae	<i>Cladium californicum</i> 6	Pteridaceae
<i>Petrophytum caespitosum</i> 12	<i>Lobelia cardinalis</i> subsp. <i>graminea</i>	Fabaceae	<i>Adiantum capillus-veneris</i> 20
Scrophulariaceae	Cyperaceae	<i>Cercis occidentalis</i> var. <i>orbiculata</i>	Primulaceae
<i>Castilleja linariifolia</i>	<i>Carex sp.</i> 9	Fagaceae	<i>Primula specuicola</i> T
Ulmaceae	Fagaceae	<i>Quercus gambelii</i> 3	Ranunculaceae
<i>Celtis reticulata</i>	<i>Quercus gambelii</i>	Juncaceae	<i>Aquilegia micrantha</i> T
<u>GLCA Dune HG R = 20</u>	Liliaceae	<i>Juncus arcticus</i> 13	Rosaceae
Agavaceae	<i>Zigadenus vaginatus</i> T	Oleaceae	<i>Petrophytum caespitosum</i>
<i>Yucca</i> sp. 7	Oleaceae	Scrophulariaceae	<i>Mimulus eastwoodiae</i> 1
Anacardiaceae	<i>Fraxinus</i> sp. 2	Asteraceae	<u>GLCA Hook HG R = 28</u>
<i>Rhus aromatica</i> var. <i>simplicifolia</i> 3	Orchidaceae	<i>Artemisia ludoviciana</i> subsp. <i>ludoviciana</i> 4	
Asteraceae	<i>Epipactis gigantea</i>	<i>Herrickia glauca</i> var. <i>glauca</i> 4	Asteraceae
<i>Sympotrichum chilense</i> T	Poaceae	<i>Brickellia longifolia</i> var. <i>longifolia</i>	<i>Carex aurea</i>
<i>Cirsium rydbergii</i> 9	<i>Andropogon glomeratus</i> var. <i>scabriglumis</i> 69	<i>Cirsium rydbergii</i> 49	<i>Carex curvatorum</i>
<i>Solidago velutina</i> subsp. <i>sparsiflora</i> 2	<i>Dichanthelium acuminatum</i>	<i>Solidago</i> sp.	Equisetaceae
Cyperaceae	<i>Phragmites australis</i>	<i>Sonchus asper</i>	<i>Equisetum hyemale</i> 2
<i>Carex</i> sp. 19	Polemoniaceae	Cyperaceae	<i>Equisetum laevigatum</i>
Oleaceae	<i>Gilia aggregata</i> var. <i>maculata</i> 2	<i>Adiantum capillus-veneris</i> 9	Fagaceae
<i>Fraxinus anomala</i>	Pteridaceae	<i>Primula specuicola</i> 1	<i>Quercus gambelii</i> 2
Orchidaceae	<i>Adiantum capillus-veneris</i> 4	Ranunculaceae	Juncaceae
<i>Epipactis gigantea</i>	Primulaceae	<i>Clematis ligusticifolia</i> 1	<i>Juncus arcticus</i> 9
Poaceae	<i>Primula specuicola</i>	Rhamnaceae	Liliaceae
<i>Andropogon glomeratus</i> var. <i>scabriglumis</i> 1	<i>Petrophytum caespitosum</i>	<i>Rhamnus betulifolia</i> 1	<i>Maianthemum stellatum</i> 5
<i>Bromus tectorum</i> T	<u>GLCA Graffiti HG R = 8</u>	Rosaceae	Orchidaceae
<i>Calamagrostis scopulorum</i> 7	Asteraceae	<i>Petrophytum caespitosum</i> 1	<i>Epipactis gigantea</i> T
<i>Muhlenbergia andina</i> T	<i>Brickellia longifolia</i> var. <i>longifolia</i>		
<i>Dichanthelium acuminatum</i>	Orchidaceae		
Pteridaceae	<i>Epipactis gigantea</i> 5		
<i>Adiantum capillus-veneris</i> 6			
Primulaceae			
<i>Primula specuicola</i> 1			

Poaceae	<u>GLCA Lower Cow HG</u>	<u>GLCA Rattlesnake HG</u>
<i>Agrostis exarata</i>	R = 12	R = 20
<i>Andropogon glomeratus</i> var. <i>scabriglumis</i> T		
<i>Bromus tectorum</i> T		
<i>Calamagrostis scopulorum</i> T		
<i>Elymus canadensis</i> 4		
<i>Muhlenbergia andina</i> 2		
<i>Muhlenbergia thurberi</i>		
<i>Dichanthelium</i>		
<i>acuminatum</i> T		
<i>Phragmites australis</i> 2		
<i>Sphenopholis obtusata</i>		
Pteridaceae		
<i>Adiantum capillus-veneris</i> 2		
Primulaceae		
<i>Primula specuicola</i>		
Ranunculaceae		
<i>Aquilegia micrantha</i>		
Scrophulariaceae		
<i>Mimulus eastwoodiae</i>		
<u>GLCA Ice HG</u> R = 17		
Anacardiaceae		
<i>Toxicodendron rydbergii</i>		
Asteraceae		
<i>Aster</i> sp.		
<i>Artemisia ludoviciana</i> subsp. <i>ludoviciana</i>		
<i>Brickellia longifolia</i> var. <i>longifolia</i>		
<i>Cirsium rydbergii</i> 29		
Cyperaceae 19		
<i>Carex lanuginosa</i>		
Equisetaceae		
<i>Equisetum</i> sp.		
Oleaceae		
<i>Fraxinus anomala</i>		
Orchidaceae		
<i>Platanthera zothecina</i>		
Poaceae		
<i>Calamagrostis scopulorum</i> T		
Pteridaceae		
<i>Adiantum capillus-veneris</i> 22		
Primulaceae		
<i>Primula specuicola</i>		
Ranunculaceae		
<i>Aquilegia micrantha</i> 3		
Rosaceae		
<i>Petrophytum caespitosum</i>		
Scrophulariaceae		
<i>Castilleja linariifolia</i>		
Scrophulariaceae		
<i>Mimulus eastwoodiae</i>		
Vitaceae		
<i>Parthenocissus vitacea</i> 7		
<u>GLCA Pedestal HG</u> R = 14		
Agavaceae		
<i>Yucca</i> sp. 4		
Asteraceae		
<i>Cirsium rydbergii</i> 7		
<i>Heterotheca villosa</i> var. <i>minor</i> T		
Cyperaceae 14		
<i>Carex aurea</i>		
<i>Carex curatorum</i>		
<u>GLCA Lower Three Garden</u>		
R = 8		
Asteraceae		
<i>Cirsium rydbergii</i> 21		
Cyperaceae 8		
<i>Carex aurea</i>		
<i>Carex curatorum</i>		
Poaceae		
<i>Dichanthelium</i>		
<i>acuminatum</i> 26		
<i>Muhlenbergia</i> sp. 2		
Primulaceae		
<i>Primula specuicola</i> 3		
Rosaceae		
<i>Petrophytum caespitosum</i>		
10		
Scrophulariaceae		
<i>Castilleja linariifolia</i> 2		
<u>GLCA Pedestal HG</u> R = 14		
Agavaceae		
<i>Yucca</i> sp. 4		
Asteraceae		
<i>Cirsium rydbergii</i> 7		
<i>Heterotheca villosa</i> var. <i>minor</i> T		
Cyperaceae 14		
<i>Carex aurea</i>		
<i>Carex curatorum</i>		
<u>GLCA Lower Cow HG</u>		
R = 12		
Juncaceae		
<i>Juncus arcticus</i> T		
Onagraceae		
<i>Oenothera longissima</i> 1		
Orchidaceae		
<i>Epipactis gigantea</i> T		
Poaceae		
<i>Calamagrostis scopulorum</i> T		
<i>Schizachyrium scoparium</i> 32		
Pteridaceae		
<i>Adiantum capillus-veneris</i> 17		
Ranunculaceae		
<i>Aquilegia micrantha</i> 1		
<i>Clematis ligusticifolia</i> 1		
Rhamnaceae		
<i>Rhamnus betulifolia</i> 1		
<u>GLCA Pyro HG</u> R = 22		
Asteraceae		
<i>Artemisia ludoviciana</i> subsp. <i>albula</i> 2		
<i>Brickellia longifolia</i> var. <i>longifolia</i> T		
<i>Cirsium rydbergii</i> 8		
<i>Conyza canadensis</i>		
<i>Pseudognaphalium</i>		
<i>luteoalbum</i>		
<i>Sonchus arvensis</i>		
<i>Sonchus asper</i>		
Cyperaceae		
<i>Carex aurea</i> 9		
<i>Scirpus</i> sp.		
Fabaceae		
<i>Cercis occidentalis</i> var. <i>orbiculata</i>		
Fagaceae		
<i>Quercus gambelii</i>		
Orchidaceae		
<i>Epipactis gigantea</i> T		
Poaceae		
<i>Bromus rubens</i>		
<i>Elymus canadensis</i> T		
<i>Muhlenbergia andina</i>		
<i>Dichanthelium</i>		
<i>acuminatum</i> 1		
<i>Polypogon monspeliensis</i>		
Pteridaceae		
<i>Adiantum capillus-veneris</i> 68		
Primulaceae		
<i>Primula specuicola</i>		
Scrophulariaceae		
<i>Mimulus eastwoodiae</i>		
Tamaricaceae		
<i>Tamarix ramosissima</i>		
Typhaceae		
<i>Typha</i> sp. 6		
<u>GLCA Stone Basin HG</u>		
R = 15		
Anacardiaceae		
<i>Toxicodendron rydbergii</i> 1		
Apocynaceae		
<i>Apocynum cannabinum</i> 11		
Asteraceae		
<i>Conyza canadensis</i> T		
<i>Pseudognaphalium</i> sp. 2		
<i>Solidago</i> sp. 4		
Campanulaceae		
<i>Lobelia cardinalis</i> subsp. <i>graminea</i>		
Cyperaceae		
<i>Carex</i> sp. 4		
Poaceae		
<i>Andropogon glomeratus</i> var. <i>scabriglumis</i>		

<i>Bouteloua curtipendula</i> var. <i>caespitosa</i>	Pteridaceae <i>Adiantum capillus-veneris</i> 1	Ranunculaceae <i>Aquilegia micrantha</i> 2	Typhaceae <i>Typha</i> sp.
<i>Calamagrostis scopulorum</i> T	Primulaceae <i>Primula specuicola</i> T	Rhamnaceae <i>Rhamnus betulifolia</i> 2	NABR AM HG R= 5
<i>Elymus canadensis</i> 3	Rosaceae <i>Petrophytum caespitosum</i>	Rosaceae <i>Petrophytum caespitosum</i> 2	
<i>Dichanthelium</i> <i>acuminatum</i> 14	Scrophulariaceae <i>Castilleja linariifolia</i>	Scrophulariaceae <i>Castilleja linariifolia</i> 2	
Pteridaceae <i>Adiantum capillus-veneris</i> 4	<i>Mimulus eastwoodiae</i> T	Ulmaceae <i>Celtis reticulata</i>	
Scrophulariaceae <i>Castilleja linariifolia</i>	<u>GLCA Wrong HG R = 10</u>	Urticaceae <i>Parietaria pensylvanica</i> T	
Vitaceae <i>Parthenocissus vitacea</i> 10	Anacardiaceae <i>Toxicodendron rydbergii</i> 11	<u>GLCA Zigy HG R = 30</u>	
<u>GLCA Swallow HG R = 11</u>	Apocynaceae <i>Apocynum cannabinum</i>	Agavaceae <i>Yucca toftiae</i>	<u>NABR Fir HG R=11</u>
Asteraceae <i>Cirsium rydbergii</i>	Asteraceae <i>Artemisia ludoviciana</i> subsp. <i>mexicana</i> T	Apocynaceae <i>Apocynum cannabinum</i> T	
<i>Sonchus</i> sp. T	<i>Solidago velutina</i> subsp. <i>sparsiflora</i>	Asteraceae <i>Artemisia ludoviciana</i> subsp. <i>ludoviciana</i>	
Cyperaceae <i>Carex aurea</i> 18	Fagaceae <i>Quercus gambelii</i> 1	<i>Cirsium rydbergii</i> 21	
Orchidaceae <i>Platanthera zothecina</i> 3	Poaceae <i>Andropogon glomeratus</i> var. <i>scabriglumis</i> 25	<i>Conyza canadensis</i>	
Poaceae <i>Calamagrostis scopulorum</i> T	<i>Calamagrostis scopulorum</i> 28	<i>Sonchus asper</i>	
Pteridaceae <i>Adiantum capillus-veneris</i> 42	Polemoniaceae <i>Gilia aggregata</i> var. <i>maculata</i>	Cyperaceae 3	
Primulaceae <i>Primula specuicola</i> 2	Pteridaceae <i>Adiantum capillus-veneris</i> 30	<i>Carex aurea</i>	
Ranunculaceae <i>Aquilegia micrantha</i> 6	<u>GLCA Zephyr HG R = 17</u>	<i>Carex curatorum</i>	
<i>Clematis ligusticifolia</i>	Agavaceae <i>Yucca</i> sp. 12	<i>Eleocharis rostellata</i> 12	
Rosaceae <i>Rubus neomexicanus</i>	Anacardiaceae <i>Rhus aromatica</i> var. <i>simplifolia</i> 2	<i>Scirpus</i> sp.	
Scrophulariaceae <i>Mimulus eastwoodiae</i>	Asteraceae <i>Cirsium rydbergii</i> 31	Fabaceae <i>Oxytropis</i> sp.	
<u>GLCA Upper Three HG R = 16</u>	Cyperaceae <i>Carex curatorum</i> 4	Liliaceae <i>Zigadenus vaginatus</i> 13	
Asclepiadaceae <i>Asclepias latifolia</i>	Fagaceae <i>Quercus gambelii</i>	Onagraceae <i>Oenothera longissima</i>	
Asteraceae <i>Solidago velutina</i> subsp. <i>sparsiflora</i>	Orchidaceae <i>Epipactis gigantea</i> T	Orchidaceae <i>Epipactis gigantea</i> T	
<i>Cirsium rydbergii</i> 40	Poaceae <i>Andropogon glomeratus</i> var. <i>scabriglumis</i>	Poaceae <i>Agrostis exarata</i>	
Cyperaceae <i>Carex aurea</i> 15	Asteraceae <i>Muhlenbergia asperifolia</i>	<i>Bromus tectorum</i>	
Fabaceae <i>Cercis occidentalis</i> var. <i>orbiculata</i>	Cyperaceae <i>Muhlenbergia thurberi</i>	<i>Calamagrostis scopulorum</i> 6	
Fagaceae <i>Quercus gambelii</i> 1	Fagaceae <i>Dichanthelium acuminatum</i>	<i>Muhlenbergia asperifolia</i>	
Orchidaceae <i>Epipactis gigantea</i> 1	Orchidaceae <i>Phragmites australis</i> T	<i>Muhlenbergia thurberi</i>	
Poaceae <i>Calamagrostis scopulorum</i> 13	Pteridaceae <i>Schizachyrium scoparium</i> 10	<i>Dichanthelium acuminatum</i>	
<i>Muhlenbergia</i> sp. 1	Primulaceae <i>Adiantum capillus-veneris</i> 1	<i>Phragmites australis</i> T	
<i>Dichanthelium acuminatum</i>	Primulaceae <i>Primula specuicola</i> T	Pteridaceae <i>Schizachyrium scoparium</i> 10	
<i>Schizachyrium scoparium</i> 15	Pteridaceae <i>Adiantum capillus-veneris</i> 2	Ranunculaceae <i>Aquilegia micrantha</i> 1	

Liliaceae
Zigadenus vaginatus 19

Orchidaceae
Epipactis gigantea T

Pinaceae
Pinus edulis

Poaceae
Calamagrostis scopulorum 4
Muhlenbergia thurberi 5

Ranunculaceae
Aquilegia micrantha T
Clematis ligusticifolia

Rhamnaceae
Rhamnus betulifolia 4

Rubiaceae
Galium multiflorum var.
coloradoense

NABR Micro HG R = 4

Asteraceae
Cirsium sp. 3
Erigeron kachinensis 6

Poaceae
Calamagrostis scopulorum 3

Ranunculaceae
Aquilegia micrantha 48

NABR Petro HG R = 9

Asteraceae
Cirsium undulatum 11
Erigeron kachinensis 7
Heterotheca villosa var.
minor T

Cyperaceae
Carex aurea 11

Gentianaceae
Swertia radiata

Orchidaceae
Platanthera sp. 1

Poaceae
Calamagrostis scopulorum
 35

Pteridaceae
Adiantum capillus-veneris T

Ranunculaceae
Aquilegia micrantha T

NABR Slickrock HG R = 14

Asteraceae
Cirsium sp. 13
Cirsium arizonicum var.
bipinnatum
Cirsium undulatum
Heterotheca villosa var.
minor

Cyperaceae
Carex aurea 2

Fagaceae
Quercus gambelii

Gentianaceae
Swertia radiata

Juncaceae
Juncus arcticus 12

Liliaceae
Zigadenus vaginatus T

Pteridaceae
Adiantum capillus-veneris 34

Rosaceae
Petrophytum caespitosum

NABR Long HG R = 10

Berberidaceae
Berberis repens

Gentianaceae
Swertia radiata

Asteraceae
Erigeron kachinensis

Liliaceae
Zigadenus vaginatus

Pinaceae
Pinus edulis

Poaceae
Calamagrostis scopulorum 4

Ranunculaceae
Aquilegia micrantha 14

Rhamnaceae
Rhamnus betulifolia

Rosaceae
Cercocarpus montanus

Rubiaceae
Galium multiflorum var.
coloradoense

NABR Micro HG R = 4

Asteraceae
Cirsium sp. 3
Erigeron kachinensis 6

Poaceae
Calamagrostis scopulorum 3

Ranunculaceae
Aquilegia micrantha 48

NABR Petro HG R = 9

Asteraceae
Cirsium undulatum 11
Erigeron kachinensis 7
Heterotheca villosa var.
minor T

Cyperaceae
Carex aurea 11

Gentianaceae
Swertia radiata

Orchidaceae
Platanthera sp. 1

Poaceae
Calamagrostis scopulorum
 35

Pteridaceae
Adiantum capillus-veneris T

Ranunculaceae
Aquilegia micrantha T

NABR Slickrock HG R = 14

Asteraceae
Cirsium sp. 13
Cirsium arizonicum var.
bipinnatum
Cirsium undulatum
Heterotheca villosa var.
minor

Cyperaceae
Carex aurea 2

Fagaceae
Quercus gambelii

Gentianaceae
Swertia radiata

Juncaceae
Juncus arcticus 12

Liliaceae
Zigadenus vaginatus T

Orchidaceae
Platanthera sp.

Pinaceae
Pinus edulis 2

Poaceae

ZION Canyon Overlook II
HG R = 26

Asteraceae
Artemisia ludoviciana subsp.
albula 3

Poaceae
Brickellia californica
Brickellia grandiflora 6

Ranunculaceae
Erigeron sionis T

Rhamnaceae
Heterotheca villosa var.
minor 1

Asteraceae
Cirsium undulatum 5

Cyperaceae
Carex aurea 8

Gentianaceae
Swertia radiata 4

Juncaceae
Juncus arcticus

Pinaceae
Pinus edulis T

Poaceae
Calamagrostis scopulorum
 40

Ranunculaceae
Aquilegia micrantha 2

Rhamnaceae
Rhamnus betulifolia

ZION Canyon Overlook I
HG R = 14

Aceraceae
Acer negundo var. *violaceum*

Asteraceae
Brickellia californica 2
Ageratina herbacea
Perityle tenella T
Stephanomeria pauciflora

Fagaceae
Quercus turbinella T

Orchidaceae
Epipactis gigantea 16

Poaceae
Muhlenbergia thurberi 5
Poa fendleriana

Pteridaceae
Adiantum capillus-veneris 34

Rosaceae
Holodiscus dumosus
Petrophytum caespitosum T

Saxifragaceae
Heuchera rubescens

Scrophulariaceae
Castilleja sp.

ZION Court of the
Patriarchs HG R = 20

Aceraceae
Acer negundo var. *negundo* T

Agavaceae
Yucca utahensis

Asteraceae
Artemisia ludoviciana subsp.
ludoviciana

Poaceae
Perityle tenella
Solidago missouriensis
Sonchus asper

Cyperaceae
Carex aurea 5

Equisetaceae	<u>ZION Falling Water HG</u>	<i>Cirsium neomexicanum</i>	Hydrophyllaceae
<i>Equisetum laevigatum</i> 5	R = 21	Berberidaceae	<i>Phacelia heterophylla</i>
Liliaceae		<i>Berberis repens</i> T	Juncaceae
<i>Maianthemum stellatum</i> 2		Brassicaceae	<i>Juncus ensifolius</i> var.
Oleaceae		<i>Erysimum capitatum</i>	<i>montanus</i> T
<i>Fraxinus velutina</i>		Caprifoliaceae	Liliaceae
Orchidaceae		<i>Symporicarpos</i> sp.	<i>Maianthemum stellatum</i> T
<i>Epipactis gigantea</i>		Celastraceae	Oleaceae
Poaceae		<i>Pachystima myrsinoides</i>	<i>Fraxinus velutina</i>
<i>Agrostis exarata</i>		Hydrangiaceae	Orchidaceae
<i>Calamagrostis scopulorum</i>		<i>Jamesia americana</i> var.	<i>Epipactis gigantea</i>
13		<i>zionis</i>	Poaceae
<i>Muhlenbergia</i> sp. 14		Liliaceae	<i>Agrostis exarata</i>
<i>Poa pratensis</i> 5		<i>Maianthemum stellatum</i> 2	<i>Calamagrostis scopulorum</i>
Pteridaceae		Poaceae	40
<i>Adiantum capillus-veneris</i> 13		<i>Bromus ciliatus</i>	<i>Muhlenbergia andina</i> 1
Rosaceae		<i>Calamagrostis scopulorum</i>	<i>Dichanthelium</i>
<i>Petrosymnum caespitosum</i>		33	<i>acuminatum</i> 2
Rubiaceae		Pteridaceae	<i>Phragmites australis</i> 1
<i>Galium trifidum</i>		<i>Adiantum capillus-veneris</i> 1	<i>Poa pratensis</i> 2
Saxifragaceae		<i>Adiantum aleuticum</i>	<i>Danthonia californica</i> T
<i>Parnassia palustris</i> var.		Primulaceae	Pteridaceae
<i>montanensis</i>		<i>Dodecatheon pulchellum</i>	<i>Adiantum capillus-veneris</i> 3
Scrophulariaceae		var. <i>zionense</i> 19	Ranunculaceae
<i>Mimulus cardinalis</i>		Ranunculaceae	<i>Aquilegia chrysanthemum</i> 2
ZION Fall HG R = 14		<i>Aquilegia formosa</i> var.	<i>Aquilegia formosa</i> var.
Araliaceae		<i>formosa</i>	<i>formosa</i>
<i>Aralia racemosa</i> subsp.		Rosaceae	<i>Clematis ligusticifolia</i>
<i>bicrenata</i>		<i>Amelanchier alnifolia</i>	Rosaceae
Asteraceae		<i>Cercocarpus intricatus</i>	<i>Petrosymnum caespitosum</i>
<i>Erigeron sionis</i>		<i>Holodiscus dumosus</i>	Rubiaceae
<i>Taraxacum officinale</i>		<i>Petrosymnum caespitosum</i>	<i>Galium trifidum</i>
Brassicaceae		Rubiaceae	Saxifragaceae
<i>Nasturtium officinale</i>		<i>Galium triflorum</i> T	<i>Heuchera rubescens</i>
Juncaceae		Saxifragaceae	<i>Parnassia palustris</i> var.
<i>Juncus ensifolius</i> var.		<i>Heuchera rubescens</i>	<i>montanensis</i>
<i>montanus</i> T		Scrophulariaceae	Scrophulariaceae
Liliaceae		<i>Mimulus cardinalis</i> 6	<i>Mimulus cardinalis</i> T
<i>Maianthemum stellatum</i> 6		Violaceae	Violaceae
Orchidaceae		<i>Viola nephrophylla</i> 2	<i>Viola</i> sp. 1
<i>Epipactis gigantea</i>		ZION Kaye's HG R = 30	ZION Lower Emerald HG
Poaceae		Anacardiaceae	R = 12
<i>Agrostis exarata</i>		<i>Toxicodendron rydbergii</i> 1	Anacardiaceae
Pteridaceae		Asteraceae	<i>Toxicodendron rydbergii</i>
<i>Adiantum capillus-veneris</i> 40		<i>Artemisia ludoviciana</i> subsp.	Asteraceae
Primulaceae		<i>ludoviciana</i> T	<i>Herrickia glauca</i> var.
<i>Dodecatheon pulchellum</i>		<i>Cirsium arizonicum</i>	<i>glauca</i> 1
var. <i>zionense</i> 32		<i>Taraxacum officinale</i> T	Cyperaceae
Ranunculaceae		Cyperaceae 19	<i>Carex aurea</i>
<i>Aquilegia chrysanthemum</i> 2			Liliaceae
<i>Aquilegia formosa</i> var.		<i>Carex curvula</i>	<i>Maianthemum stellatum</i> 3
<i>formosa</i>		Equisetaceae	Orchidaceae
Rosaceae		<i>Equisetum hyemale</i>	<i>Epipactis gigantea</i> 1
<i>Petrosymnum caespitosum</i>		Fagaceae	Poaceae
Scrophulariaceae		<i>Quercus turbinella</i>	<i>Agrostis exarata</i> 5
<i>Mimulus cardinalis</i>			<i>Calamagrostis scopulorum</i>
			33

Pteridaceae
Adiantum capillus-veneris 1

Primulaceae
Dodecatheon pulchellum
 var. *zionense* 25

Ranunculaceae
Aquilegia chrysanthra T

Scrophulariaceae
Mimulus cardinalis

Vitaceae
Vitis arizonica

ZION Menu Falls HG R = 23

Aceraceae
Acer negundo var. *negundo*

Anacardiaceae
Toxicodendron rydbergii

Apocynaceae
Apocynum cannabinum

Asteraceae
Baccharis salicina
Cirsium arizonicum
Sonchus asper

Cyperaceae T
Carex aurea
Carex curatorium

Equisetaceae
Equisetum laevigatum

Fagaceae
Quercus turbinella

Liliaceae
Maianthemum stellatum

Oleaceae
Fraxinus velutina

Poaceae
Agrostis exarata
Bromus diandrus
Calamagrostis scopulorum
 13
Polypogon viridis
Muhlenbergia sp. 6

Pteridaceae
Adiantum capillus-veneris 16

Ranunculaceae
Aquilegia chrysanthra 9
Aquilegia formosa var.
 formosa
Clematis ligusticifolia

Rosaceae
Petrophytum caespitosum

Scrophulariaceae
Mimulus cardinalis 15

ZION Narrows Trail HG
R = 26

Aceraceae
Acer negundo var. *negundo* 4

Anacardiaceae
Toxicodendron rydbergii T

Asteraceae
Artemisia ludoviciana subsp.
ludoviciana
Brickellia longifolia var.
longifolia
Cirsium neomexicanum
Cirsium wheeleri
Sonchus asper

Berberidaceae
Berberis repens

Cannabaceae
Humulus lupulus var.
neomexicanus

Cyperaceae
Carex aurea T

Liliaceae
Maianthemum stellatum 19

Orchidaceae
Epipactis gigantea

Poaceae
Bromus ciliatus
Bromus diandrus
Calamagrostis scopulorum
 26
Elymus glaucus
Muhlenbergia andina
Achnatherum hymenoides

Pteridaceae
Adiantum capillus-veneris 8

Primulaceae
Dodecatheon pulchellum
 var. *zionense* 13

Ranunculaceae
Aquilegia chrysanthra 1
Aquilegia formosa var.
formosa
Clematis ligusticifolia T

Rosaceae
Petrophytum caespitosum

Scrophulariaceae
Mimulus cardinalis T

Vitaceae
Vitis arizonica 3

ZION Pine Creek HG R = 6

Asteraceae
Herrickia glauca var.
glauca 8
Solidago velutina subsp.
sparsiflora

Poaceae
Calamagrostis scopulorum
Poa fendleriana

Pteridaceae
Adiantum capillus-veneris

Primulaceae
Dodecatheon pulchellum
 var. *zionense* 6

ZION Snail HG R = 13

Anacardiaceae
Toxicodendron rydbergii

Asteraceae
Herrickia glauca var. *glauca*

Liliaceae
Maianthemum stellatum T

Oleaceae
Fraxinus velutina

Orchidaceae
Epipactis gigantea

Poaceae
Bromus ciliatus
Calamagrostis scopulorum
 15
Polypogon viridis

Pteridaceae
Adiantum capillus-veneris 32

Ranunculaceae
Aquilegia chrysanthra 1

Rosaceae
Petrophytum caespitosum

Rubiaceae
Galium aparine var.
echinospermum

Scrophulariaceae
Mimulus cardinalis

ZION Trail's End HG R = 13

Asteraceae
Cirsium arizonicum var.
arizonicum
Sonchus arvensis
Sonchus asper

Berberidaceae
Berberis repens

Cyperaceae 3
Carex aurea
Carex curatorium

Equisetaceae
Equisetum arvense

Liliaceae
Maianthemum stellatum 20

Oleaceae
Fraxinus velutina 1

Onagraceae
Oenothera longissima

Orchidaceae
Epipactis gigantea T

Poaceae
Bromus tectorum
Calamagrostis scopulorum
 20
Elymus canadensis 3
Muhlenbergia andina 1

Pteridaceae
Adiantum capillus-veneris

Primulaceae
Dodecatheon pulchellum
 var. *zionense* 20

Ranunculaceae
Aquilegia chrysanthra T
Aquilegia formosa var.
formosa

Rosaceae
Petrophytum caespitosum

Saxifragaceae
Heuchera rubescens

Scrophulariaceae
Mimulus cardinalis

<i>Mimulus guttatus</i>	Berberidaceae	Poaceae	<i>Aquilegia formosa</i> var. <i>formosa</i>
Violaceae	<i>Berberis repens</i>	<i>Bromus diandrus</i> T	<i>Clematis ligusticifolia</i>
<i>Viola</i> sp. 3	Cyperaceae 7	<i>Calamagrostis scopulorum</i>	Rosaceae
Vitaceae	<i>Carex aurea</i>	18	<i>Petrophytum caespitosum</i> 1
<i>Vitis arizonica</i>	<i>Carex curotorum</i>	<i>Muhlenbergia thurberi</i>	Rubiaceae
<u>ZION Weeping Rock HG</u>	Fagaceae	<i>Panicum</i> sp.	<i>Galium multiflorum</i> var. <i>multiflorum</i>
R = 28	<i>Quercus gambelii</i>	<i>Phragmites australis</i> 2	Scrophulariaceae
Apocynaceae	<i>Quercus turbinella</i>	<i>Polygonum interruptus</i> 8	<i>Mimulus cardinalis</i> 30
<i>Apocynum cannabinum</i> 1	Liliaceae	Pteridaceae	Tamaricaceae
Asteraceae	<i>Maianthemum stellatum</i> 7	<i>Adiantum capillus-veneris</i> 7	<i>Tamarix ramosissima</i>
<i>Artemisia ludoviciana</i> subsp. <i>ludoviciana</i> 1	Linaceae	Primulaceae	Ulmaceae
<i>Cirsium arizonicum</i> var. <i>arizonicum</i>	<i>Linum lewisii</i>	<i>Dodecatheon pulchellum</i>	<i>Celtis reticulata</i>
	Oleaceae	var. <i>zionense</i> 2	Violaceae
	<i>Fraxinus velutina</i>	Ranunculaceae	<i>Viola</i> sp. T
		<i>Aquilegia chrysantha</i> 7	

¹possibly *Andropogon glomeratus*; vegetative sample

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